SENSORS & CONTROLS

Project Fact Sheet

On-line Laser-Ultrasonic Measurement System

Benefits

- Fiber coupling for both detection and generation that can be conveniently serviced in the harsh environment of the steel and other metal industries
- Performance not affected by dust, fumes, vibrations, shocks, and large changes of temperature
- On-line measurement to allow adjustments of machinery on the fly
- Cost savings of $86 M per year in seamless mechanical tube piercing; $234 M per year if adopted throughout the U.S. steel seamless tube and pipe industry
- Potential reduction of energy consumption by $6x10^{12}$ Btu per year, greenhouse emissions by 0.3 M metric tons carbon equivalent per year, and toxic waste by 0.26 M pounds per year

Applications

The complete fiber-coupled laser-ultrasonic system can be readily adapted for real-time, on-line applications in the steel, aluminum, and casting industries, including:

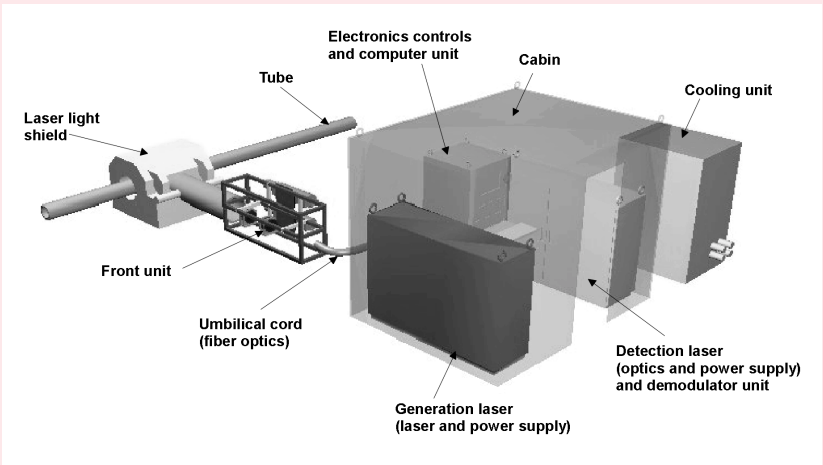
- measurement of wall thickness and eccentricity of seamless tubes during piercing, elongation, reduction, and sizing operations
- evaluation of the microstructure of steel tubing during hot rolling
- detection of internal flaws in continuous casting of steel
- measurement of the internal temperature of steel and metal objects
- detection of surface defects in large structures
- detection of foreign particles in molten steel or other liquid metal

Laser-ultrasonic system will provide on-line measurement of wall thickness and eccentricity of steel tubing for manufacturing control

On-line, laser-based ultrasonic measurement of thickness and eccentricity will improve productivity of seamless mechanic steel tubing by 30-50% and will correspondingly reduce energy consumption and the emission of pollutants. Current production runs need to be halted for manual measurement at the beginning of each run for machinery adjustments to meet the product specifications, resulting in a typical loss of three tubes for a production run of ten tubes. With on-line measurement, adjustments could be made during the production of the first tube, with no need to halt for manual measurement and no need to waste additional tubes to check if the adjustments are correct. Further productivity improvement through immediate feedback could be expected from a significant reduction in tubing scraps due to out-of-tolerance wall dimension and from optimization of the stock (additional wall thickness) requirement to adjust for the eccentric inner diameter caused by the piercing operation—thus, reducing the subsequent cost for its removal.

An estimated cost savings of $86 M per year would be realized if the laser-ultrasonic technology were applied throughout the U.S. steel seamless mechanical tubing industry to control the piercing process and reduce the safety tolerance associated with eccentricity. If all seamless tube and pipe mills in the United States adopted the technology, the minimum total documentable cost savings to the steel industry would be $234 M per year.

Laser-Ultrasonic System



Schematic of the laser-ultrasonic system.

Project Description

Goal: Develop and demonstrate a laser-ultrasonic system to measure wall thickness and eccentricity of steel seamless mechanical tubing in a piercing mill.

The wall thickness of the rotating and translating tube will be measured with ultrasound generated and detected by lasers. The thickness of the wall at the measurement location will be determined from the measurement of the time of flight between two consecutive echoes (or the initial surface pulse and the first echo, if the second echo is unavailable) and knowledge of the acoustic velocity. Velocity calibration as a function of temperature will be obtained by heating a piece of steel of the same grade and monitoring temperature on line by a pyrometer. More precisely, since the calibration takes into account thermal expansion, the on-line measurement will yield the wall thickness when the tube is at ambient temperature.

The coordinates of the measurement points on the tube surface will be obtained by two Laser Doppler Velocimetry (LDV) systems. Two simultaneous velocity measurements will be made and numerically integrated to determine displacement from a known starting point. One LDV system will measure the displacement along the tube axis, whereas the other will measure the circumferential displacement. A thickness map of the tube will be plotted, and from this information eccentricity will be determined at various locations along the tube axis.

This laser-ultrasonic system integrated with velocimetry and pyrometry measurement techniques will operate from a standoff distance (several feet), perform 100 ultrasonic measurements of wall thickness per second and determine the coordinates of the measurement locations on the tube at the same rate, and provide a complete thickness map of the tube to determine eccentricity. The specifications of the integrated laser-ultrasonic system will include:

- an accuracy and precision of wall thickness measurement of 0.0005" and ±0.5% at room temperature, respectively,
- a ±0.2" maximum position error along tube length, and
- a ±0.1 rotation maximum position error along the circumference.

Progress and Milestones

This project was awarded in January 1999 through a FY 1998 solicitation issued jointly by the Steel Industry of the Future and the Sensors and Controls Program. Project tasks are scheduled for completion in 30 months. Key tasks that have been performed or are planned are:

- The breadboard laser-ultrasonic system will be industrially hardened, and advanced signal processing will be incorporated.
- The laser-ultrasonic system will be demonstrated at The Timken Company at two process locations in a piercing mill. In a related effort, Industrial Material Institute (IMI, a teaming partner of this project) has tested a laser-ultrasonic system online at LTV Steel Company in Cleveland for measuring the mechanical properties of cold-rolled sheet on an inspection line, under contract with the American Iron and Steel Institute and OIT.
- After development of selection criteria, a potential supplier of the laser-ultrasonic technology developed during the project will be selected for technology transfer and commercialization.

Project Partners

The Timken Company (Prime)
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National Research Council of Canada
Industrial Material Institute
Boucherville, Quebec

Oak Ridge National Laboratory
Oak Ridge, TN

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